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RESEARCH ARTICLE

A cone beam CT investigation of ponticulus posticus and lateralis in children and adolescents

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Objectives: To determine the prevalence and pathogenesis of ponticulus posticus (PP) and ponticulus lateralis (PL) in children and adolescents.
Methods: Cone beam CT scans of 576 patients were examined for PP and PL. The patients were divided into three age groups: 10 years and younger, 11–13 years and 14 years and older. Ponticulus formation was categorized as absent, partial or complete. Gender, race and location (right, left or bilateral) were recorded. Data were analysed with the χ^2 test, with significance at $p < 0.050$. Institutional review board approval was granted.
Results: Overall prevalence of PP was 26.2%, with complete lesions in 10.4%. The frequency of PP was greater in patients aged 14 years and older ($p \leq 0.038$). The occurrence of complete PP was greater in patients aged 11 years and older ($p = 0.028$). Lesions were more common in males ($p = 0.014$) and in blacks compared with other non-white races ($p = 0.035$). Bilateral PP was more common than right-sided lesions ($p = 0.008$) and more frequent in the oldest cohort ($p = 0.006$). Overall prevalence of PL was 6.1% (3.0% complete), with no differences between age groups, genders, races or by location.
Conclusions: PP is not uncommon even in the first decade and increases in frequency, completeness of calcification and numbers in mid-adolescence. It appears to be more common in males and in blacks. PP may be a congenital osseous anomaly of the atlas that mineralizes at various times. PL is less frequent with no demographic predilections.
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Ponticulus posticus (PP) (Latin for "little posterior bridge") is a bony anomaly of the atlas that consists of a complete or partial calcified bridge over the vertebral groove of the posterior arch.[1–30] The vertebral artery passes through the groove in its path from the transverse foramen into the foramen magnum, accompanied by the suboccipital nerve. Ponticulus lateralis (PL) ("little lateral bridge") is formed by a bony growth extending from the lateral side of the superior articular process of the atlas laterally and inferiorly towards the lateral process.[3,5–7,10–12,15,26] The anomaly can also be complete or partial.

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PP and PL have been investigated anatomically[1–12,20] and radiographically.[13–28] However, reports of the prevalence of PP range from 1.3% to 45.9%.[1–26] There is also disagreement about the frequency of complete *vs* partial bridges.[1–7,9,11,13–23] PL appears to be less common, but reported prevalence varies from 1.1% to approximately 19%.[3,5–7,11,12,15,26] Conflicting research has been published regarding the occurrence of ponticuli in different age groups,[4,5,9,11,13,14,16–19,21,24] including children.[13,14,16–18,21] There is no consensus regarding the prevalence of PP and PL in males compared with females,[4,5,7–9,11–22,24] or in different ethnic and racial populations.[6,7,9,11,15,16,22] The predilection of PP and PL for right *vs* left sides is also unclear.[2,4,5,7,9,11–15,22] The absence of definitive trends in the frequency, demographics and location of PP and PL has impeded attempts to fully understand the pathogenesis of these lesions.

Recognition of ponticuli in the atlas is important, because they have been implicated in the development of otherwise unexplainable neck pain and headaches, visual disturbances, problems with speech and swallowing, vertigo and vascular problems.[4,5,7–10,20,24,27–29] Recently, a relationship between PP and the Gorlin–Goltz syndrome has been observed.[30] Misidentification of PP can result in errors during vertebral surgery, which could damage these structures.[1,15,16,22,23] For these reasons, careful radiographic evaluation of the cervical spine should be performed for the presence of PP or PL.

Cone beam CT (CBCT) has great advantages over planar skull radiography in visualizing the cervical vertebrae. It enables depiction of the vertebral column in three planes of space, thereby providing the benefits of conventional CT with generally lower radiation exposure and greater spatial resolution.[31] It is possible that the use of CBCT in the evaluation of PP and PL in large populations in the first two decades may permit more accurate determination of the demographic features and a better understanding of the causes of these lesions.

The objective of the project was to determine the prevalence of PP and PL in a population of children and adolescents as visualized in CBCT scans acquired for orthodontic diagnosis. Data were evaluated regarding the distribution of lesions according to patient age, completeness of lesion calcification, gender and racial or ethnic grouping and location (right, left or bilateral) in an attempt to ascertain the pathogenesis of the abnormalities.

Methods and materials

The project was approved by the institutional review board of the University of Detroit Mercy, Detroit, MI (#1213-75). CBCT scans of patients between the ages of 5 and 17 years were evaluated. The patients had been referred to the University of Detroit Mercy Oral and Maxillofacial Imaging Centre between March 2009 and March 2012 for orthodontic diagnosis and treatment planning. All scans were acquired with the i-CAT® 17–19 unit (Imaging Sciences International, Hatfield, PA) using scanning parameters of 120 kVp, 5 mAs and an exposure time of 8.9 s, with a voxel size of 0.3 mm. The acquired volume was at least 16 × 8 cm.

A diplomate of the American Board of Oral and Maxillofacial Radiology with over 20 years' experience evaluated the scans of 583 patients. Of these, 7 scans were excluded owing to excessive motion unsharpness, resulting in a sample size of 576 scans. The mean age of the patients was 12.2 years, with a median of 12 years. The mode of the population was 14 years. No information was provided regarding the patients' medical history or signs and symptoms of disease in the head and neck areas.

Scan data were reconstructed and images were viewed with i-CAT® Vision software v. 1.8.1.10, on a flat screen desktop monitor with 1024 × 780 spatial resolution (Dell, Round Rock, TX). Ponticulus posticus was evaluated by scrolling from right to left on the sagittal view. PL was evaluated by scrolling from anterior to posterior on the coronal view.

Patients were stratified into three age groups:

Group A: 10 years and younger, a period of time generally preceding puberty.

Group B: 11–13 years, a period corresponding to early puberty.

Group C: 14–17 years, a period considered to represent late or post-puberty.

The right and left sides of each atlas were categorized as to the presence or absence of PP using the following classification, modified from Cederberg et al[17] and Stubbs[19]:

- Class 1: no calcifications across the pathway of the vertebral artery (Figure 1).
- Class 2: calcification extending less than halfway across the artery (Figure 2).
- Class 3: calcification extending at least halfway but not completely across the artery (Figure 3).
- Class 4: calcification extending completely over the pathway of the artery (Figure 4).

Classification of PL was based on similar criteria:

- Class 1: no calcifications extending between the articular and lateral processes.
- Class 2: calcification extending less than halfway laterally from the articular process.

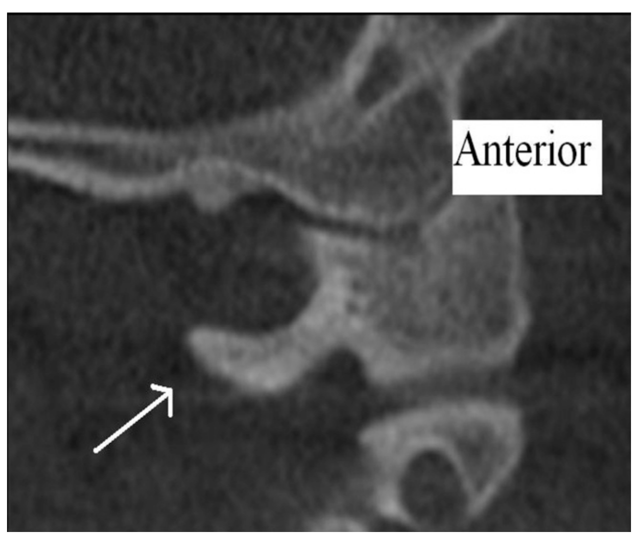

Figure 1 Cone beam CT sagittal section of an atlas without ponticulus posticus (Class 1) in a 16-year-old black female. The arrow indicates a normal segment of the posterior arch.

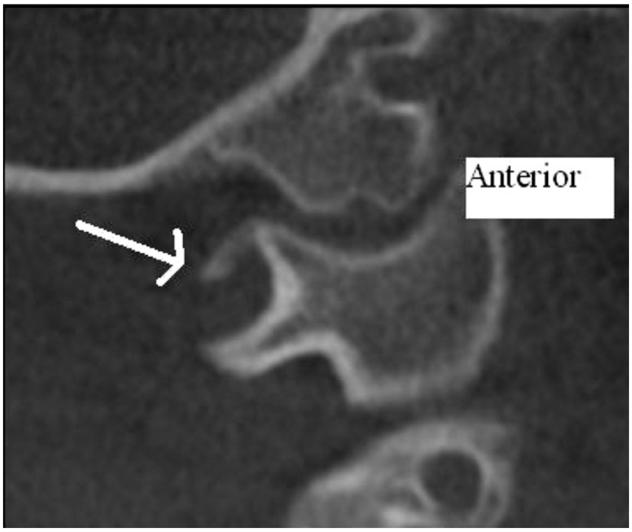

Figure 2 Cone beam CT sagittal section reveals a Class 2 partial ponticulus posticus on the left side of the atlas of an 11-year-old white female (arrow).

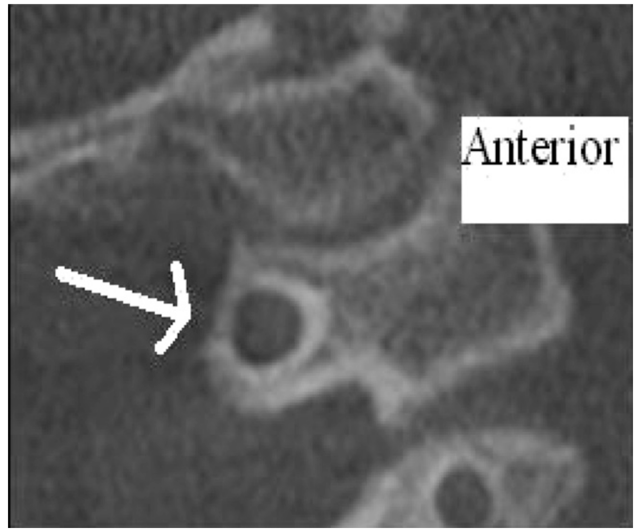

Figure 4 Cone beam CT sagittal section visualizes a complete Class 4 ponticulus posticus on the left side of the atlas of a 14-year-old black female (arrow).

- Class 3: calcification extending at least halfway from the articular process but not contacting the lateral process.
- Class 4: calcification extending completely over the lateral process (Figure 5).

Data were also collected regarding the patients' gender and racial/ethnic grouping as determined in the patients' electronic records.

Statistical analysis included χ^2 tests for significance of differences in prevalence of PP and PL between age groups, degree of calcification, gender and racial or ethnic grouping as determined from the patients' electronic records and lesion location. *Post hoc* comparisons between groups were made when necessary.

Results

A total of 151 of the 576 patients exhibited at least one PP, for an overall prevalence of 26.2%. A significant difference was found between age groups ($p = 0.014$), as listed in Table 1. *Post hoc* comparisons revealed that lesions were more likely in Group C (the age 14–17 years group) than in patients in Group A ($p = 0.006$) or

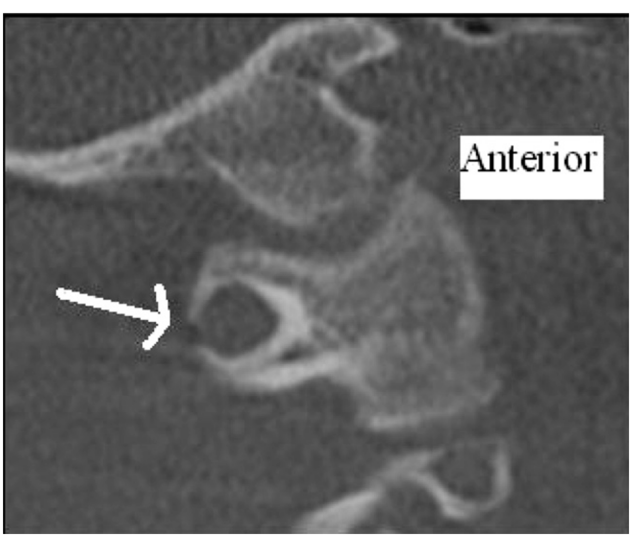

Figure 3 Cone beam CT sagittal section depicts a Class 3 ponticulus posticus on the right side (arrow). The patient is a 14-year-old black male.

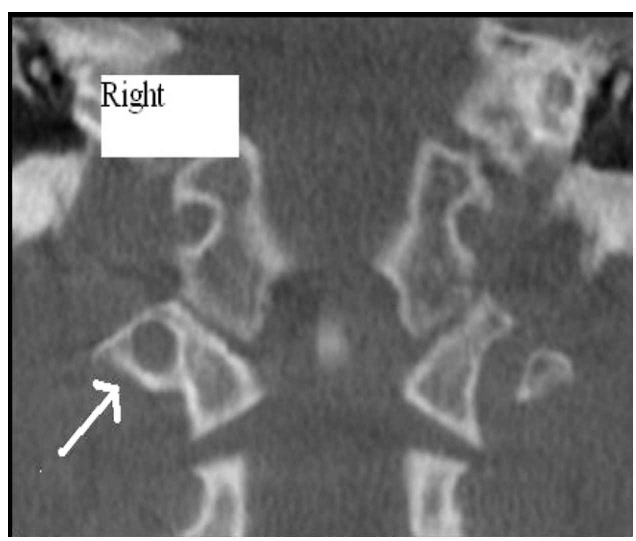

Figure 5 Cone beam CT viewed in the coronal plane reveals a complete Class 4 ponticulus lateralis on the right side of Class 1, indicated by the arrow. The left side is normal. The patient is a 14-year-old white female.

Table 1 Lesions by age group

Age group (years)	*Total patients*	*Ponticulus posticus*	*%*		*Ponticulus lateralis*	*%*	
A: ≤10	166	34	20.5	$p = 0.014$	8	4.8	$p = 0.724$
B: 11–13	212	51	24.0		14	6.6	
C: 14–17	198	66	33.3		13	6.6	
Total	576	151	26.2		35	6.1	

B ($p = 0.038$). The difference between Groups A and B was not significant ($p = 0.409$). PL was identified in 35 patients (6.1%). There was no difference between age groups in the likelihood of PL ($p = 0.724$).

At least one Class 4 PP lesion was identified in 60 patients (10.4%), as indicated in Table 2. A total of 91 individuals (15.8%) had at least one Class 2 or 3 bridge without a Class 4 PP. Patients over the age of 10 years had a significantly greater prevalence of complete PP compared with children 10 years and younger ($p = 0.028$). Complete PL bridges were detected in 17 patients, or 3.0% of the population. A total of 18 individuals had Class 2 or 3 lesions without a Class 4 lesion (3.1%). No significant differences were found between age cohorts for either condition ($p = 0.828$).

Significantly more male patients were identified with PP than females ($p = 0.014$) but no difference between genders was detected for PL ($p = 0.592$), as shown in Table 3. Racial groups were classified for the purposes of statistical examination as black, white and other, a category that included people of Asian, Middle Eastern and unknown or mixed ancestry (Table 4). A significant difference in frequency of PP was identified between these groups ($p = 0.041$). *Post hoc* analysis determined that PP was significantly more common in blacks than in patients classified as "other" ($p = 0.035$). The difference between blacks and whites approached significance ($p = 0.053$), with no difference between whites and others ($p = 0.307$). However, no racial differences were noted for PL ($p = 0.201$).

The total number of PP bridges was 216, with 79 Class 2, 56 Class 3 and 81 Class 4 lesions. Of the 216 PP lesions, 38 occurred on the right side of the atlas, 48 on the left side and 130 occurred bilaterally in 65 patients. Overall, there was a significant difference in frequencies of different locations ($p = 0.025$), with a *post hoc* test indicating that bilateral lesions were more likely than right-side lesions ($p = 0.008$). Differences between bilateral and left and between left and right were not significant ($p \geq 0.110$). Lesions by location are stratified by age group in Table 5. The omnibus comparison did not reveal significant differences in location between age groups ($p = 0.101$). However, a planned contrast was performed in place of a *post hoc* analysis, and the Bonferroni adjustment was made to account for multiple comparisons (lowering the α level of significance to 0.0167). It was discovered that bilateral lesions were significantly more likely to occur in the 14–17 years of age cohort than the other groups ($p = 0.006$), and that in this age group bilateral bridges were more common than PP on the right side ($p = 0.004$); bilateral lesions were more likely to occur than bridges on the left side, but this fell short of significance with the Bonferroni correction ($p = 0.023$). No significance was found in the distribution of PL lesions overall ($p = 0.063$), between any age groups ($p = 0.377$), or within any groups using planned contrast analysis ($p \geq 0.023$).

Discussion

In this investigation, the overall prevalence of PP was 26.2%, similar to the results of many researchers.[5,6,11,15,18,19,21,24] At least one complete PP bridge was detected in 10.4% of patients. This is consistent with the findings of complete PP in skeletal samples[2,4–7,9,19,20,23] and radiographic examinations.[13,17–21] Other authors, however, have reported a smaller percentage of atlases exhibiting complete PP in anatomical specimens[1,3,8,11] and radiographs.[14,16,22–24] The identification of partial PP in 15.8% of patients is comparable to some published research.[14,18,21] It exceeds the findings of some authors working with anatomical specimens[1–4,6] and radiographs,[19,20,22] but other research suggests greater percentages of patients with partial lesions.[5,7,11,17,20] The published data represent many different ethnic and racial groups, which may explain at least in part the wide range of percentages of affected vertebrae. It is also possible that the lack of standardized criteria for partial PP may affect the data, making comparisons between reports difficult. Classifications of partial PP vary among the many articles reporting this anomaly. What might be classified as a partial PP by one observer may be interpreted as a deep sulcus in the posterior arch by others. Disagreement between observers was a problem in identification of partial lesions in one study, and the authors recommended standardization of criteria for this abnormality.[25]

Our results are within the reported range of prevalence for children and adolescents.[13,14,16–18,21] Some

Table 2 Patients with at least one complete lesion

Age group (years)	*Total patients*	*Ponticulus posticus: complete*	*%*		*Ponticulus lateralis: complete*	*%*	
A: ≤10	166	10	6.1	$p = 0.028$	4	2.4	$p = 0.828$
B and C: 11–17	410	50	12.2		13	3.2	
Total	576	60	10.4		17	3.0	

Table 3 Prevalence of lesions in males *vs* females

Gender	*Total patients*	*Ponticulus posticus*	*%*		*Ponticulus lateralis*	*%*	
Female	305	67	22.0	$p = 0.014$	17	5.6	$p = 0.592$
Male	271	84	31.0		18	6.6	
Total	576	151	26.2		35	6.1	

studies of PP using only lateral cephalometrics revealed frequencies similar to our findings[13,21] but others discovered fewer affected patients,[14,16] especially for partial lesions.[14,18] One possible explanation for differences in radiographic detection may be the use of CBCT in the present investigation. This technique allows the observer to view thin sections of tissue, eliminating the problem of superimposition on planar images.[4,7,9] Investigators examining both lateral cephalometric and CT radiographs have discovered significantly greater numbers of patients with PP, and more partial bridges, with the three-dimensional CT scans,[15,22] although some of the difference in one study might have been due in part to the greater prevalence of CT patients with cervical spine symptoms.[15] Other investigators have found a much smaller percentage of bridges on lateral skull radiographs than on anatomical specimens and suggested that planar radiography may underestimate the true prevalence.[9,20]

We found increasing percentages of patients with PP from the youngest to the oldest age group, with significantly greater prevalence in patients aged 14 years and older compared with the younger groups. This suggests that PP bridges can form early in childhood (the youngest patient with a lesion in our series was 5 years of age) but they may form more frequently after puberty. Similar trends have been reported among patients in the first two decades.[13,14,18]

This investigation found a significantly greater proportion of males with PP. This is in disagreement with many investigations that reported a female predilection[4,7,18,19] or an equal distribution between males and females.[5,13–15,17,21,22,24] Our results suggest that the male predilection may be due in part to the large proportion of black males with PP. Our data revealed that PP is significantly more common in blacks than the other non-white races ($p = 0.035$), so racial differences exist. Other researchers have also noted greater proportions of lesions in blacks.[9,11] An investigation of atlases in Africans documented high percentages for complete (14.2%) and partial (39.2%) PP.[7]

Our data indicate that the percentage of patients with at least one Class 4 PP increases from 6.0% in the first decade to >12% in the older cohorts. There is a significantly greater number of Class 4 complete bridges compared with Class 2 and 3 partial PP in children older than 10 years of age. This suggests that partial bridges progress to complete lesions as children age, a finding that has been reported previously in children[11,18] and adults.[5,11] The theory that partial PP continues ossification to produce complete lesions was rejected in one investigation because of the finding that partial bridges were more common in females while complete bridges predominated in males.[19] Other writers have proposed that partial lesions result from a regressive loss of the middle part of the complete bridge,[3,5,20] and that the lesions themselves regress with age.[14,20] But the finding of a greater percentage of complete lesions in the older cohort suggests that this does not happen, at least in the first two decades.

PP is often said to represent ossification of portions of the posterior atlanto-occipital membrane. This is discounted by some authors, who note that mineralization of ligaments is generally a late occurrence in life and would not be a plausible explanation for PP occurring in children.[20,24] It has been proposed that the prevalence of PP is increased in manual labourers and may have some relation to carrying heavy loads in the neck and shoulder.[5,7,11] Our finding of PP in approximately 25% of individuals in the first two decades would seem to contradict these theories. It is also unlikely that PP arises as a hypertrophic adaptation or osteophyte formation, considering the presence of bridges in very young children.

Our findings agree with Mitchell,[9] who believed that PP is not a degenerative change related to ageing. The number of partial and complete bridges in children 10 years of age and younger, as discovered in the present investigation, is comparable to data published regarding adults, which would call such hypotheses into question. It is more likely that PP is congenital or genetic in nature, a concept that may be supported by the finding of cartilaginous precursors to bone bridges in young children.[20] It is also possible that PP develops from the dorsal arch of the pro-atlas or represents a similar osseous anomaly of the atlas that exhibits varying degrees of mineralization over time.[23]

Table 4 Prevalence of lesions by race

Race	*Total patients*	*Ponticulus posticus*	*%*		*Ponticulus lateralis*	*%*	
Black	236	74	31.4	$p = 0.041$	10	4.2	$p = 0.201$
White	278	66	23.7		22	7.9	
Other[a]	62	11	17.7		3	4.8	
Total	576	151	26.2		35	6.1	

[a]Other includes patients of Asian, Middle Eastern and unknown or mixed ancestry.

Table 5 Locations of lesions by age group

Age group (years)	*Ponticulus posticus right*	*Ponticulus posticus left*	*Ponticulus posticus bilateral*		*Ponticulus lateralis right*	*Ponticulus lateralis left*	*Ponticulus lateralis bilateral*	
A: ≤10	10	14	10	$p = 0.101$	4	2	2	$p = 0.377$
B: 11–13	10	20	21		4	7	3	
C: 14–17	18	14	34		2	9	2	
Total	38	48	65		10	18	7	

There was a greater frequency of bilateral bridges than unilateral PP in our population. Similar results have been reported.[1,6,7,9,14,20,22] The significantly greater occurrence of bilateral PP in the oldest age cohort suggests that lesions are not only more likely to increase in prevalence and completeness later in childhood but that they are more likely to develop on more than one side with increasing age. It also provides further evidence that ponticuli are neither degenerative changes nor lesions that disappear over time. Further investigation of unilateral *vs* bilateral occurrence in adults should be conducted with three-dimensional imaging.

Our findings reveal that PL is much less common than PP, in accordance with other published data.[3,5–7,11,12,15] The frequencies of complete (3.0%) and partial (3.1%) PL in the present research exceed most reported figures, which vary from 1.1% to 19%. This wide range may reflect the relative scarcity of data on PL. But it is possible that the generally higher prevalence, both complete and partial, in the present investigation results from the use of CBCT, which allows visualization of small calcifications that could be overlooked on static skull radiographs. In one investigation, PL was identified on CT scans in 6.2% of patients, similar to our results with CBCT.[15]

PL does not seem to demonstrate any predilection for specific age groups and does not appear to differ between genders, racial groups or anatomic location. Other investigators have identified significant differences in location, with most cases on the left side[3,15] or the right side.[7] It might be concluded that PL does not arise through the same mechanism as PP. It is possible that PL, like PP, may vary among different racial and ethnic populations. The paucity of investigations of PL, however, limits the breadth of any conclusions about this lesion.

The significance of recognizing PP and PL has been emphasized by many authors. Posterior and lateral bridges can compress the vertebral artery during rotational movements of the spine, leading to vertebrobasilar insufficiency syndrome.[5,7–11,20] In one report, 13 of 77 patients with PP had symptoms of vertebrobasilar insufficiency in the absence of other explainable causes.[20] Compression of the vertebral artery is a cause of Barre–Lieou syndrome, which includes headache, retro-orbital pain, vasomotor disturbances of the face and difficulty with vision, phonation and swallowing. The syndrome has been related to PP by many authors,[7,9–11,20,27,28] and removal of the ponticuli has been reported to relieve the symptoms.[27,28] Vertebral artery tethering and dissection have been reported in cases of PP.[29] Headache, neck and shoulder/arm pain as well as vertigo have been found with significantly greater frequency in patients with complete PP compared with partial PP.[4] Leonardi et al[30] identified PP on the lateral skull radiographs of 9 of 18 patients with the Gorlin–Goltz syndrome. The bridges were complete in seven patients and partial in two, and PP was the only sign of soft tissue calcification in three patients. For these reasons, dentists who examine CBCT images should carefully evaluate the atlas for PP and PL, especially if patients exhibit otherwise unexplainable manifestations of vertebral artery disorders or signs of the Gorlin–Goltz syndrome. Although causality has not been established between ponticuli and any of these conditions, the association is sometimes evident.

Some researchers caution that misinterpretation of PP as part of the dorsal arch could lead to the erroneous placement of lateral mass screws as treatment for instability of the atlanto-axial complex, with subsequent damage to the vertebral artery.[1,15,16,22,23] Although it has been argued that PP does not put the artery in the path of a lateral mass fixation device,[8] some authors recommend careful examination of three-dimensional radiographs when planning such treatment.[15,16,22]

In conclusion, PP is not a rare finding in childhood and adolescence, even in the first decade, and seems to become more common after the age of 13 years. It appears that partial PP lesions progress to complete bridges early in adolescence and that they may also increase in number, as indicated by the significantly greater number of bilateral cases in the older cohort. The abnormalities appear to be more common in males as well as in blacks compared with other non-white races. PP does not appear to be regressive or degenerative in nature, and there does not appear to be a need for extra loads on the atlanto-occipital junction to produce ponticuli. It may be a congenital or genetic condition or an anatomic variation that arises and mineralizes at various times in early life. PL does not exhibit any of the demographic or site predilections shown with PP, which suggests that this anomaly may differ in pathogenesis from PP. CBCT is effective in detecting small lesions that may be unseen on planar radiographs. Dentists examining CBCT scans should look carefully for PP and PL, because these abnormalities may be related to otherwise unexplainable head and neck pain and other symptoms related to compression of the vertebral artery and suboccipital nerve.

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